PAN-PACIFIC ENTOMOLOGIST
66(3): 217–226, (1990)

SURVEY OF POTENTIAL ARTHROPOD PARASITOIDS AND PREDATORS OF *CHRYSOLINA* SPP. (COLEOPTERA: CHRYSOMELIDAE) ASSOCIATED WITH ST. JOHNSWORT IN NORTHERN IDAHO

C. L. Campbell[1] and J. P. McCaffrey
Department of Plant, Soil and Entomological Sciences,
University of Idaho, Moscow, Idaho 83843

Abstract.—Parasitic and predatory arthropods associated with St. Johnswort, *Hypericum perforatum* L., dominated habitats were surveyed for association in time and space with various life stages of *Chrysolina quadrigemina* Suffrian and *C. hyperici* Forster. No parasites of any *Chrysolina* spp. lifestage were found during two years of intensive survey efforts. Potential predators of *Chrysolina* spp. were found and included ground beetles, crickets, and spiders. Although the ground-dwelling arthropods and the chrysomelids occur together in time and space, whether any predation of *Chrysolina* spp. actually occurs remains unknown.

Key Words.—Insecta, *Chrysolina quadrigemina, Chrysolina hyperici,* biological control, *Hypericum perforatum,* Klamath weed, goatweed

Hypericum perforatum L. (Clusiaceae), St. Johnswort, infested large areas of northern Idaho rangeland until suppressed by *Chrysolina quadrigemina* Suffrian, *C. hyperici* Forster (Coleoptera: Chrysomelidae) and *Agrilus hyperici* Creutzer (Coleoptera: Buprestidae). Tisdale (1976) reported that since the establishment of these herbivores, St. Johnswort infestations in northern Idaho have been maintained at about 3% of the infestation level present in 1948.

Despite the reduction in St. Johnswort stands, outbreaks still occur. The weed exists along roadsides and in small infestations up to several hectares in size. These outbreaks may be due to abiotic disruptions that influence the plant-herbivore relationship (Williams 1985) or interference with *C. quadrigemina* by its natural enemies. Wilson (1943) reported that predators and parasites and the availability of adequate food supply were the principal factors adversely affecting populations of *C. quadrigemina* in their native habitats in France. Williams (1985) addressed the importance of abiotic factors such as precipitation patterns in mediating the interactions between *Chrysolina* spp. and *H. perforatum*; however, there have been few studies on the role of biotic factors such as predators and parasites on limiting the herbivores' impact where they have been introduced. As Goeden & Louda (1976) noted, mortality inflicted on colonized phytophages by native organisms is a commonly suspected, but only occasionally demonstrated cause of unsuccessful biological control.

In France, the principal parasite of *C. quadrigemina* and *C. hyperici* is *Anaphes* sp. (Hymenoptera: Mymaridae), which attacks the eggs. A tachinid, *Macquartia occlusa* Rondani, attacks larvae of *C. quadrigemina.* Adult *C. quadrigemina* are attacked by the ant, *Acanthomyops niger* L., and the reduviid bug, *Rhinocoris erythropus* L. (Wilson 1943). In Australia, a delay in the establishment of *Chrysolina hyperici* Forster was attributed in part to attack by predators such as ants,

[1] Current address: 103 E. Fremont #7, Selah, Washington 98942.

bugs, spiders, and birds (Wilson & Campbell 1943). No egg parasitism was found in Australia even ten years after introduction of both chrysomelids, but a tachinid, *Froggattimyia* sp., which normally attacked native chrysomelids (*Paropsis* spp.), was found attacking *Chrysolina* spp. larvae. Parasitism of *C. quadrigemina* and *C. hyperici* never exceeded 1% and 3% respectively in 1949 (Clark 1953). In Canada, Smith (1958) reported that no parasitoids (or predators) of importance were observed on *Chrysolina* spp. in British Columbia. In the United States, Huffaker (1967) stated that entomophagous parasitoids were of relatively no concern in California or Australia. Neither Smith nor Huffaker provided supporting data.

In Australia, an ant, *Chalcoponera cristulata* Forel, was the principal predator of *Chrysolina* spp. larvae, but populations of this species and other suspected predators such as the carabids, *Sarticus esmeraldipennis* Castelnaud and *Diaphoromerus germari* Castelnaud, and the lycosids, *Lycosa pictiventris* L. Koch and *L. godeffroyi* L. Koch, were considered to be too low to have destroyed a large proportion of the *Chrysolina* spp. larval population (Clark 1953). Smith (1958) initially suspected that an ant, possibly *Formica obscuripes* Forel, was important as a mortality factor of teneral adult *C. quadrigemina* in British Columbia. However, he found that *C. quadrigemina* populations were highest within the ant colony's foraging area and suggested that the ants removed other beetle predators such as carabids and cicindelids. Huffaker (1967) noted predation of *C. quadrigemina* by earwigs and spiders, but reported that they were of no consequence.

Given the general paucity of information pertaining to the importance of parasitoids and predators of *Chrysolina* spp. in the United States, and specifically in the Pacific Northwest, we determined the faunal composition of parasitic and predatory arthropods associated with the introduced *Chrysolina* spp. at various St. Johnswort sites in northern Idaho.

Materials and Methods

Study Sites.—Four St. Johnswort-infested sites were chosen for study. The Central Grade site was situated 10.4 km NE of Lewiston (Nez Perce Co.) in the Clearwater River Canyon. The Coyote Grade site, situated 14.4 km NE of Lewiston, was also in the Clearwater River Canyon. The White Bird site was situated 6.4 km NE of White Bird (Idaho Co.) in the Salmon River valley. The Central Grade, White Bird, and Coyote Grade canyon grassland sites are all within the Pacific Northwest Bunchgrass region and their vegetation is in the *Agropyron spicatum* (Pursh.) Scribn. and Smith series (Tisdale 1976, 1986). The Farragut site was situated in Farragut State Park, 8.0 km east of Athol (Kootenai Co.). This study site was once part of a naval installation, but is currently undisturbed. This site is within the Northern Conifer region and the vegetation is in the *Pseudotsuga menziesii* (Mirbel) Franco series (Cooper et al. 1987). More detailed descriptions of the study sites are provided by Campbell & McCaffrey (in press).

Predator Survey.—Pitfall traps were used to survey ground-dwelling predators that were present during the period when *Chrysolina* spp. larvae and adults were active. Traps consisting of plastic Solo® cups (0.47 l wells with 0.26 l liners) containing a 1:1 ethylene glycol–water mixture, were arranged in a grid formed by the placement of two parallel rows of five traps separated from one another by 1 m. A parallel replicate of this arrangement was placed 2 m away for a total of 20 traps per grid. The grid design was chosen to capture arthropods from a sizeable area (at least 4 m by 4 m), while minimizing trap servicing time and plot trampling. Grids were established during early April 1985 at Central Grade, Coyote Grade and White Bird, and late April at Farragut due to the seasonal lag in *Chrysolina* spp. activity at the latter site. New traps were established in the same holes at about the same respective times in 1986. The grid at Farragut was fenced during 1986 to keep deer from destroying the traps. Twice monthly, traps were emptied and the contents of all traps from a given site were combined. Trap contents were washed to remove mud and debris and then stored in 70% ethanol. Arthropods known or suspected to be predaceous were identified and counted.

We swept St. Johnswort plants with a standard insect net (38 cm diameter) to survey foliage-dwelling predators. Fifty 180° sweeps were taken within 100 m of the pitfall sample grids twice-weekly during the period May–July. No sweep samples were taken at White Bird in 1986 because nearby St. Johnswort stands had been greatly reduced from the 1985 levels. Sweep-net contents were bagged in the field then frozen upon return to the laboratory. Predatory arthropods were later sorted, then identified to an appropriate taxonomic level.

Parasitoid Survey.—Parasitism was investigated by collecting and rearing individuals of each *Chrysolina* spp. life stage obtained during 1985 and 1986 seasons from each of the four study sites.

A total of 6247 eggs, 1340 third and fourth instars, 162 pupae, and 610 adults were hand-collected and reared or maintained on St. Johnswort cuttings in covered Petri plates (lined with moist paper towel or soil) held at 20 ± 2° C and a 14:10 (L:D) photoperiod. The Petri plates were checked every two days for the presence of parasitoids.

Results and Discussion

Predator Survey.—Table 1 lists known or suspected predatory arthropods collected at the four study sites. Pitfall traps yielded the most information on faunal composition. Adult carabids, the gryllid, *Gryllus assimilis* Fabr., and lycosid spiders made up the bulk of each catch. Sweep-net sampling gathered few individuals and few species, mainly *Oecanthus* sp. (Orthoptera: Gryllidae), *Reduviolus* sp. (Hemiptera: Nabidae) and several undetermined species of spiders.

The seasonal population trends of selected ground-dwelling predators are presented in Figs. 1–4. Only the ground-dwelling arthropods collected by pitfall trapping are included because so few potential predators were collected by sweep-sampling. The foliage-dwelling predatory arthropods may have been limited by the paucity of prey found in the upper foliage; an undetermined species of lygaeid bug was the only common inhabitant other than adult *Chrysolina* spp. and adult *A. hyperici.* The 1985 samples at Farragut represented only three sample dates because deer repeatedly destroyed the pitfall traps during the latter part of the season. In 1986, a fence erected around the pitfall trap grid successfully excluded the deer. Only the 1986 data are included in our discussion of this site.

Among the Carabidae captured, *Harpalus fraternus* LeConte, *Anisodactylus similis* LeConte, and *Amara littoralis* Mannerheim, were the most common at the Central Grade, Coyote Grade and White Bird sites (Figs. 1–3). *Zacotus matthewsi* LeConte, known as an inhabitant of dense, coniferous forests (Lindroth 1961), was generally the most common carabid at Farragut (Fig. 4). *Gryllus as-*

Table 1. Predaceous arthropods collected by pitfall trap and/or sweep-net from St. Johnswort study sites in northern Idaho, 1985 and 1986.

Taxon	Study site: Central Grade	White Bird	Coyote Grade	Farragut
INSECTA				
ORTHOPTERA				
Gryllidae				
Gryllus assimilis Fabr.	+, p[a]	+, p	+, p	+, p
Oecanthus sp.	+, p, s	+, p, s	+, p, s	–
DERMAPTERA				
Forficulidae				
Forficula auricularia L.	+, p	+, p	+, p	–
HEMIPTERA				
Nabidae				
Reduviolus	+, p, s	+, p, s	+, p, s	+, p, s
Reduviidae				
Sinea sp.	–	–	–	+, s
NEUROPTERA				
Chrysopidae				
Chrysoperla carnea (Stephans)	–	–	+, s	–
COLEOPTERA				
Carabidae				
Agonum sp.	–	+, p	–	+, p
Amara littoralis Mannerheim	+, p	+, p	+, p	–
A. obesa Say	–	+, p	+, p	–
Amara spp.	–	+, p	+, p	+, p
Anisodactylus similis LeConte	+, p	+, p	+, p	+, p
Anisodactylus spp.	–	+, p	+, p	–
Bradycellus sp.	–	+, p	–	–
Calosoma cancellatum Eschscholtz	+, p	+, p	–	+, p
C. moniliatum LeConte	–	–	–	+, p
C. tepidum LeConte	–	+, p	–	+, p
Carabus taedatus Fabr.	–	–	–	+, p
Diplocheila oregona Hatch	+, p	+, p	–	–
Harpalus caliginosus Fabr.	–	+, p	+, p	–
H. fraternus LeConte	+, p	+, p	+, p	+, p
Harpalus spp.	–	+, p	+, p	+, p
Lebia divisa LeConte	–	+, p	–	–
L. perita Casey	–	+, p	–	–
Pterostichus sp.	+, p	–	–	+, p
Scaphinotus relictus Horn	+, p	–	+, p	+, p
Zocatus matthewsi LeConte	–	–	–	+, p
Cicindelidae				
Cicindela sp.	–	–	–	+, p
Staphylinidae (no further determination)	+, p	–	–	–
HYMENOPTERA				
Formicidae[b]				
Formica spp.	+, p	+, p	+, p	+, p
ARACHNIDA				
ARANEAE[c]				
Dictynidae	+, p, s	+, p, s	+, p, s	+, p, s
Gnaphosidae	+, p	+, p	+, p	+, p
Lycosidae	+, p	+, p	+, p	+, p
Oxyopidae	+, p	+, p	–	–

Table 1. Continued.

Taxon	Study site: Central Grade	White Bird	Coyote Grade	Farragut
Philodromidae	+, p	+, p	+, p	+, p
Salticidae	+, p	+, p	+, p	+, p
Thomisidae	+, p	+, p	+, p	+, p

[a] (+) indicates presence at the site; (−) indicates absence. (p) indicates trapped by pitfall; (s) collected by sweeping.
[b] Several species of ants were collected, but only *F. subnitens* Creighton identified.
[c] Not determined beyond family level.

similis was present at all sites at various population levels (Figs. 1–4). Several different species of wolf spider (Lycosidae) were captured. One yet undetermined lycosid species was dominant at Central Grade, Coyote Grade and White Bird (Figs. 1–3) while a different species was dominant at Farragut (Fig. 4); the bulk of lycosids represented in Figs. 1–4 were these two as yet undetermined species.

The ground-dwelling predatory arthropods identified in Table 1 were considered potential predators of *Chrysolina* spp. because they were present in St. Johnswort stands at the times when larvae and adults were active (spring and early summer) and when adults became inactive upon entering their period of aestivation (beginning in late July). Furthermore, they occurred in the same microhabitat as the chrysomelids. Second-instar and older *Chrysolina* spp. larvae are found on the ground near the host-plant's base during the day and part of the night before they ascend into the St. Johnswort foliage to feed (Clark 1953). Thus, they could be discovered by the predators which occur concurrently in the same microhabitat. Teneral adult *Chrysolina* spp., which emerge from pupal cells in the soil, aestivating adults, and adults which overwinter would also be potentially available for discovery and attack by ground-dwelling species.

Although the ground-dwelling arthropods and the chrysomelids occur together in time and space, it remains unknown whether predation of *Chrysolina* spp. actually occurred because the food preferences of the presumed predatory arthropods have not been established. For example, the three most common carabids collected in our study, *H. fraternus, An. similis,* and *A. littoralis,* may not be predatory as assumed. Lindroth (1968) indicated that adults of some species of *Harpalus* and *Amara* tend toward phytophagy while species of *Anisodactylus* are comparatively more carnivorous. Barney & Pass (1986) reported that *H. pennsylvanicus* DeGeer, *A. cupreolata* Putzeys and *A. impuncticollis* Say consumed alfalfa weevil (*Hypera postica* Gyllenhal) larvae and various lepidopteran larvae as well as seeds of chickweed (*Stellaria media* L.) and crabgrass (*Digitaria* spp.) under laboratory conditions. Further study of the three common carabids found at our study sites could help determine their potential impact upon *Chrysolina* spp. The predatory nature of *G. assimilis,* the cricket commonly found at the study sites, has not been substantiated, but a related species, *G. pennsylvanicus* Burmeister, was found capable of detecting and consuming apple maggot pupae (*Rhagoletis pomonella* Walsh, Diptera: Tephritidae) in simulated natural surroundings (Monteith 1971). The possibility that *G. assimilis* might prey upon

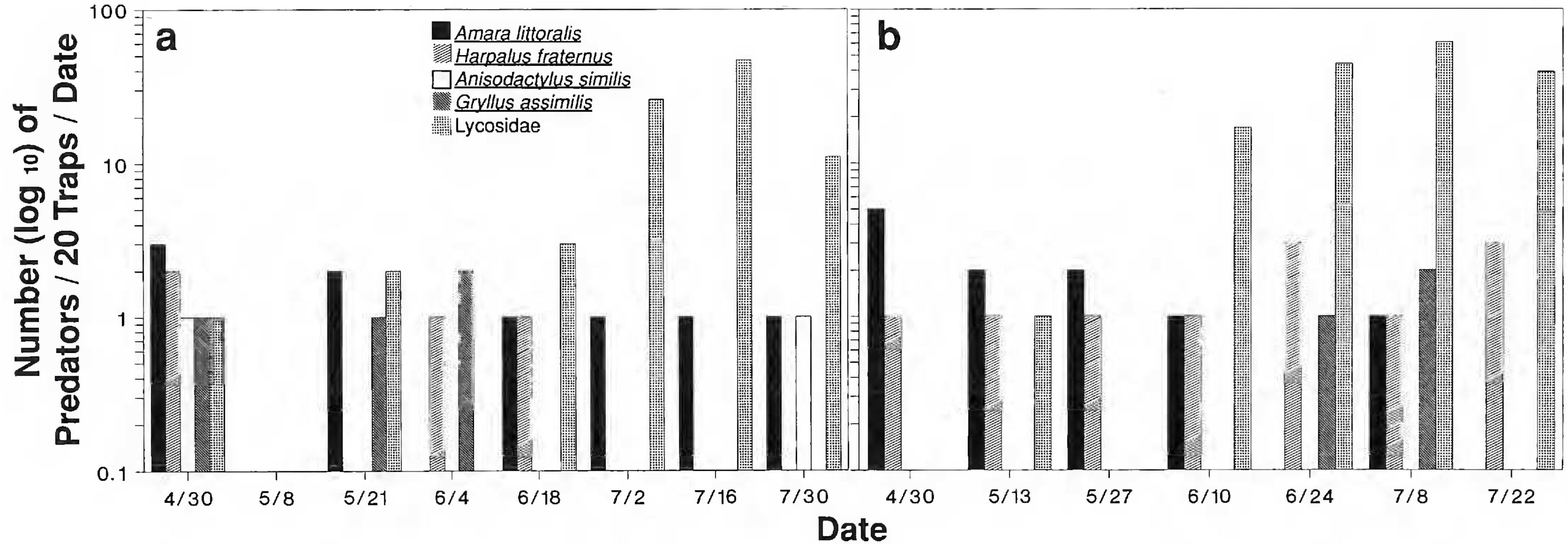

Figure 1. Relative abundance of predatory arthropods caught in pitfall traps at Central Grade, 1985 (A) and 1986 (B).

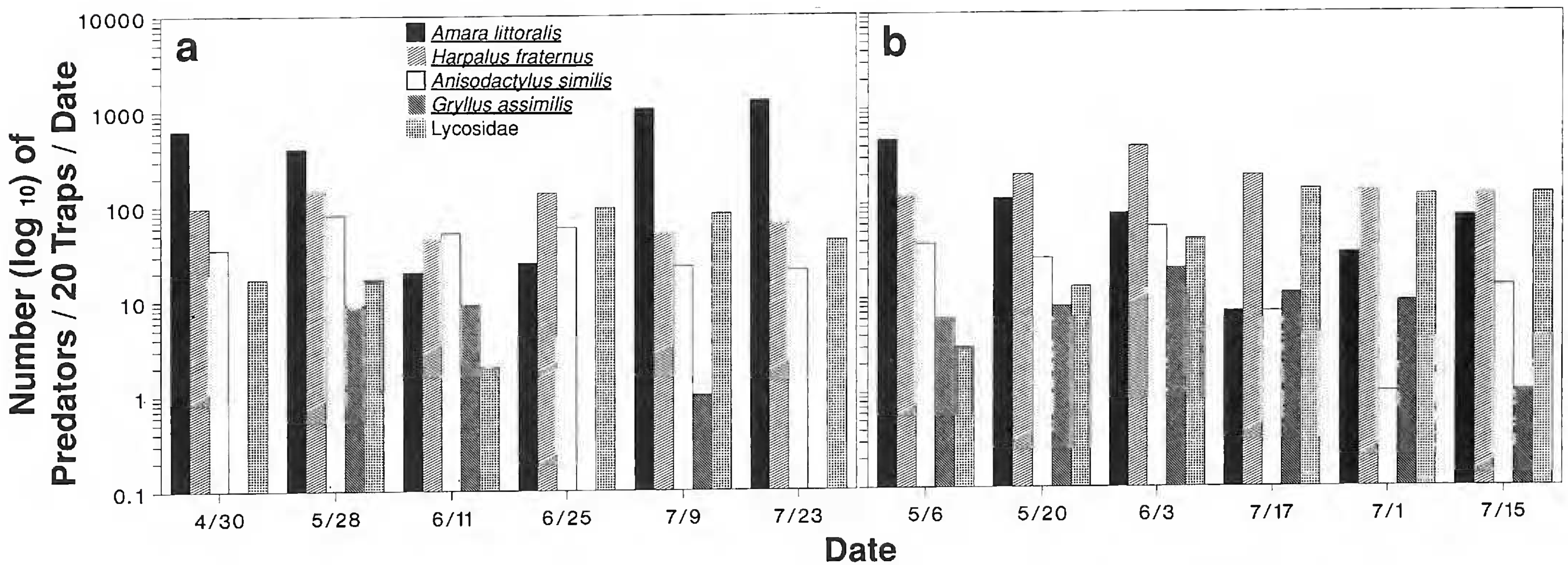

Figure 2. Relative abundance of predatory arthropods caught in pitfall traps at Coyote Grade, 1985 (A) and 1986 (B).

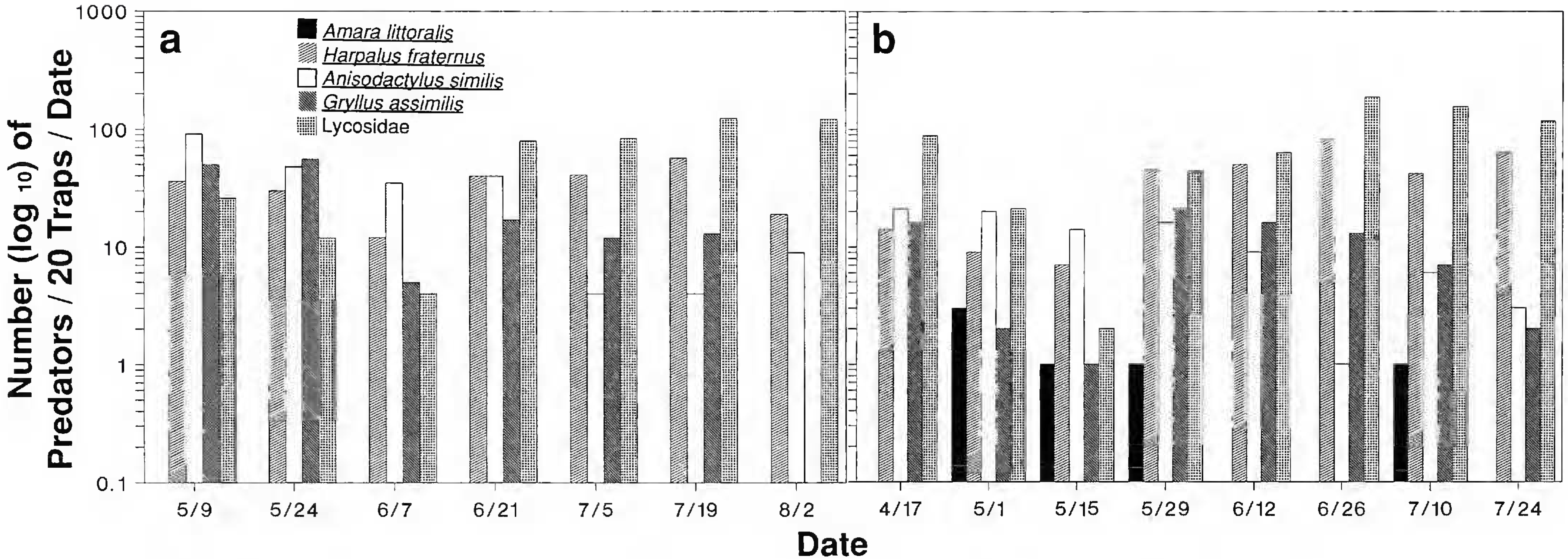

Figure 3. Relative abundance of predatory arthropods caught in pitfall traps at White Bird, 1985 (A) and 1986 (B).

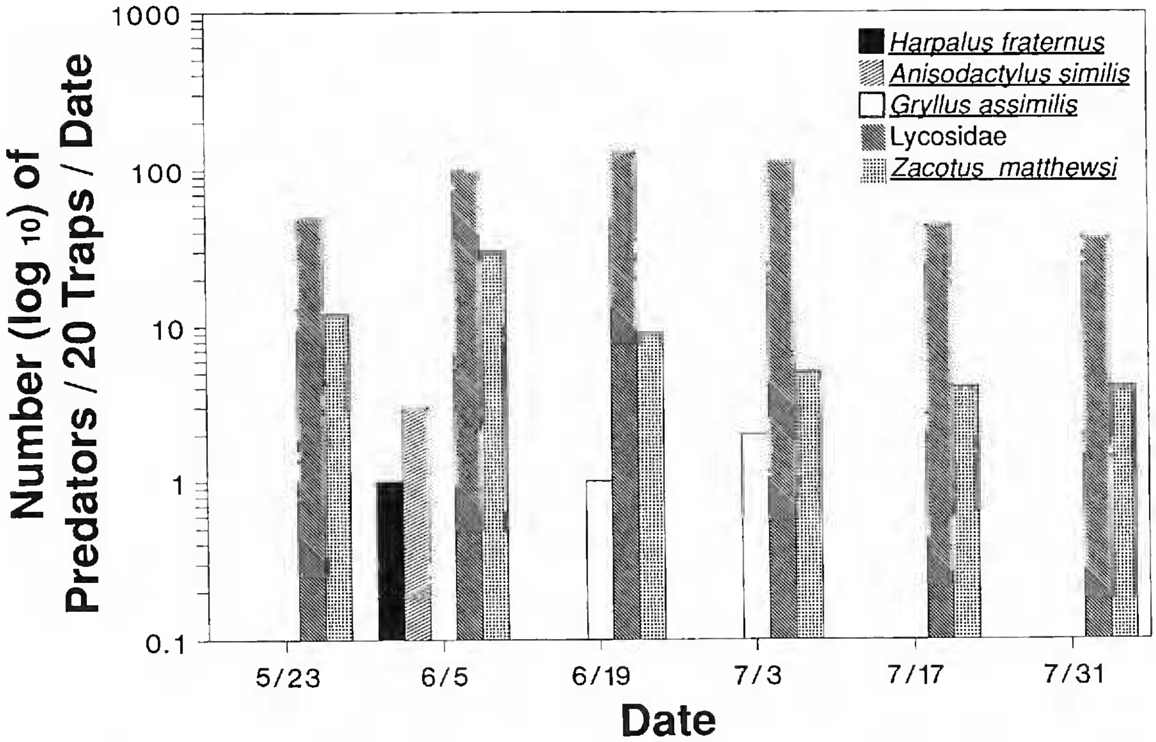

Figure 4. Relative abundance of predatory arthropods caught in pitfall traps at Farragut, 1986.

Chrysolina spp. cannot be discounted and should be similarly investigated. Lycosid spiders, which are obligate predators, could be antagonists of *C. quadrigemina* and *C. hyperici,* but this remains unknown at this time. Evaluation of the predatory role of these potential predatory species is necessary to fully understand their importance as biotic mortality factors of *Chrysolina* spp. Finally, Rees (1969) reported on a possible chemical predator deterrent in a closely related *Hypericum*-feeding species, *C. brunsvicensis* Gravenh. This chemical defense has not yet been reported for *C. quadrigemina* or *C. hyperici* and warrants further study.

Parasitoid Survey.—No parasitoid of any *Chrysolina* spp. life stage was found. This is not surprising because virtually no other chrysomelids from which parasitoids could have transferred were encountered in St. Johnswort stands; only an occasional *Timarcha intricata* Haldeman (Coleoptera: Chrysomelidae) and small alticines (Coleoptera: Chrysomelidae) were recovered from sample units containing St. Johnswort and pitfall traps in St. Johnswort stands respectively. The only native species of *Chrysolina* found in Idaho is *C. flavomarginata vidua* Rogers (Stecker 1963, Hatch 1971). It has only been found on a sagewort (*Artemisia dracunculus* L.) in southern Idaho (Stecker 1963); thus, it does not occur with *C. quadrigemina* in typical northern Idaho St. Johnswort habitats.

With parasitism lacking and predation of *C. quadrigemina* larvae and adults by endemic arthropods possibly discouraged by a chemical defense, it appears that *C. quadrigemina* and *C. hyperici* may be relatively free from mortality inflicted by other arthropod species. Further studies evaluating some of the more important potential predators encountered during this study are needed to further assess this supposition.

Acknowledgment

We thank Edwin Tisdale and William F. Barr (Departments of Range Resources and Plant, Soil & Entomological Sciences [PSES], University of Idaho, respectively) for their assistance in habitat classification and locating some of the original release sites of the *Chrysolina* spp. Bradley P. Harmon and Dennis J. Schotzko

(PSES) provided technical assistance and Dale Everson (Department of Mathematics and Applied Statistics, University of Idaho) provided statistical assistance.

We thank Edwin Tisdale, James B. Johnson (PSES), R. H. Callihan (PSES), and Dennis J. Schotzko for reviewing this manuscript. This research was supported by a grant from the William F. Barr Travel Fund and Idaho Agricultural Experiment Station Project 061-R838, a contribution project to Western Regional Project W-84. Journal artical number 89735 of the Agricultural Experiment Station, University of Idaho, Moscow, Idaho.

Literature Cited

Barney, R. J. & B. C. Pass. 1986. Foraging behavior and feeding preference of ground beetles (Coleoptera: Carabidae) in Kentucky alfalfa. J. Econ. Entomol., 79: 1334–1337.

Campbell, C. L. & J. P. McCaffrey. (in press). Population trends, seasonal phenology and impact of *Chrysolina quadrigemina* and *C. hyperici* (Coleoptera: Chrysomelidae) and *Agrilus hyperici* (Coleoptera: Buprestidae) associated with *Hypericum perforatum* in northern Idaho. Environ. Entomol.

Clark, L. R. 1953. The ecology of *Chrysomela gemellata* Rossi and *C. hyperici* Forst. and their effect on St. John's Wort in the Bright District, Victoria. Aust. J. Zool., 1: 1–69.

Goeden, R. D. & S. M. Louda. 1976. Biotic interference with insects imported for weed control. Ann. Rev. Entomol., 21: 325–342.

Hatch, M. H. 1971. The beetles of the Pacific Northwest. Part V: Rhipiceroidea, Sternoxi, Phytophaga, Rhynchophora, and Lamellicornia. University of Washington Press, Seattle.

Huffaker, C. B. 1967. A comparison of the status of biological control of St. Johnswort in California and Australia. Mushi, 39: 51–73.

Lindroth, C. H. 1961. The ground-beetles of Canada and Alaska (Part 2). Opuscula Entomol. Suppl., 20.

Lindroth, C. H. 1968. The ground-beetles of Canada and Alaska (Part 6). Opuscula Entomol. Suppl., 34.

Monteith, L. G. 1971. Crickets as predators of the apple maggot, *Rhagoletis pomonella* (Diptera: Tephritidae). Can. Entomol., 103: 52–58.

Rees, C. J. C. 1969. Chemoreceptor specificity associated with choice of feeding site by the beetle, *Chrysolina brunsvicensis* on its foodplant, *Hypericum hirsutum*. Entomol. Exp. & Appl., 12: 565–583.

Smith, J. M. 1958. Biological control of Klamath weed, *Hypericum perforatum* L., in British Columbia. Proc. 10th Int. Cong. Entomol., (1956) 4: 561–565.

Stecker, R. E. 1963. The Chrysomelidae of Idaho (Coleoptera). M.S. Thesis, University of Idaho, Moscow.

Tisdale, E. W. 1976. Vegetational responses following biological control of *Hypericum perforatum* in Idaho. Northwest Sci., 50: 61–75.

Williams, K. S. 1985. Climatic influences on weeds and their herbivores: biological control of St. John's Wort in British Columbia. pp. 127–132. *In* Delfosse, E.S. (ed.). Proceedings of the VI International Symposium Biological Control of Weeds, 19–25 August 1984, Vancouver, Canada.

Wilson, F. 1943. The entomological control of St. John's Wort (*Hypericum perforatum* L.) with particular reference to the insect enemies of the weed in southern France. Aust. Counc. Sci. Ind. Res. Bull., 169.

Wilson, F. & T. G. Campbell. 1943. Recent progress in the entomological control of St. John's Wort. J. Counc. Sci. Ind. Res., 16: 45–56.

Received 25 October 1989; accepted 9 August 1990.